PUSH-BUTTON

OSCILLATOR

MODEL 440A(R)

OPERATING AND MAINTENANCE

MANUAL

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MODEL 440A(R)

OPERATING AND MAINTENANCE MANUAL

SERIAL NO. 938

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580 Massachusetts Ave., Cambridge, Mass., 02139, U.S.A.

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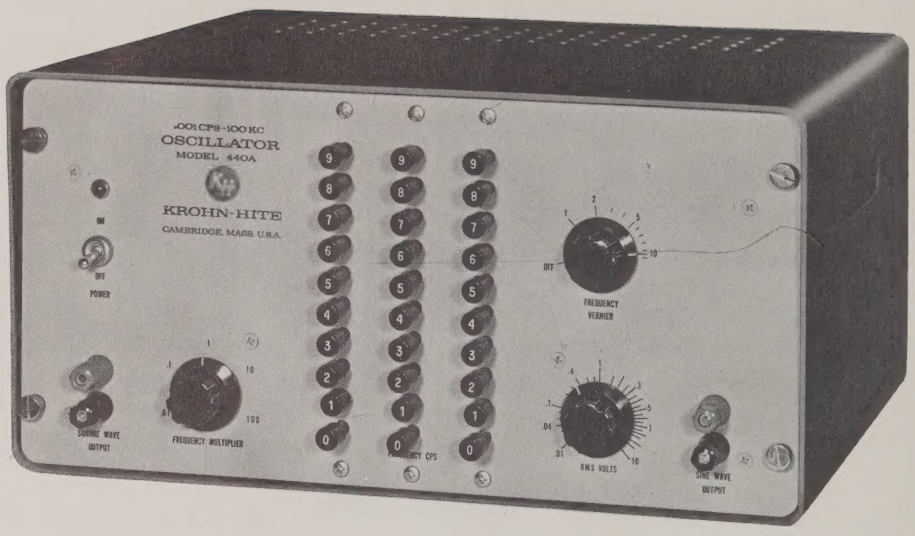

Model 440A

Model 440AR

Figure 1. Model 440A and Model 440AR Oscillators

SECTION 1

GENERAL DESCRIPTION

1.1 INTRODUCTION

The KROHN-HITE Model 440A(R) PUSH-BUTTON OSCILLATOR, shown in Figure 1, is designed for applications requiring very low distortion or good frequency stability and resettability. It provides both sine waves and square waves at any frequency between 0.001 and 100,000 cycles per seoond. It operates from an a-c source of 105-125/210-250 volts, 50-400 cycles per second. An integral power supply furnishes the heater voltages and regulated voltages required for operation.

1.2 DESCRIPTION

The Oscillator consists of a chassis and front panel assembly mounted in a case. Electrical sections are a Main Amplifier, an AVC Amplifier, a frequency determining RC Network and a Power Supply.

As shown in the simplified block diagram, Figure 4, the Model 440A(R) is a resistance-capacitance oscillator using a modified "Bridge T" RC network as the frequency determining parameter. The resistive elements in the RC network are varied by the three banks of ten push-button switches to provide fine control of frequency. Coarse control of frequency is obtained by the frequency multiplier switch which selects the required value of both capacitors in the RC network. A vernier frequency control varies the frequency continuously by an amount equal to the increment between adjacent buttons of the third switch bank with additional frequency overlap beyond 10 on the vernier dial.

The main and AVC amplifiers provide the required signals for the RC network. Amplitude stability is maintained by the AVC amplifier which uses tungsten elements of incandescent lamps as a voltage sensitive device in a resistance bridge.

The sine wave output is controlled by a logarithmically tapered potentiometer directly on the output to maintain hum and distortion in constant ratio to the output sine wave voltage. The square wave output is constant and is obtained directly from the square wave generator, which is driven by the sine wave signal.

1.3 TECHNICAL SUMMARY

FREQUENCY RANGE: 0.001 cps to 100 kc, continuously variable in five decade bands.

Bands	Multiplier	Frequency (cps)
1	1/100	0.001 - 10
2	1/10	10 - 100
3	1	100 - 1,000
4	10	1,000 - 10,000
5	100	10,000 - 100,000

FREQUENCY CONTROL: Three banks of decade push buttons with a calibrated vernier control covering the range between adjacent buttons of the third bank; vernier control is also used to cover the range from 0.001 cps to 0.01 cps when the three zero buttons are depressed.

FREQUENCY CALIBRATION ACCURACY: ±1% from 1 cps to 10 kc; ±3% from 0.01 cps to 100 kc; ±30% from 0.001 cps to 0.01 cps, after initial warm-up.

FREQUENCY STABILITY (after initial warm-up): Short term drift, less than 0.01%, drift per hour, less than 0.05%; drift, for a ±10% change in line voltage, less than ±0.05% from 1 cps to 10 kc, ±0.2% over the entire frequency range.

OUTPUT WAVEFORMS: Sine wave and square wave simultaneously.

SINE WAVE OUTPUT:

POWER (maximum): 100 milliwatts.

VOLTAGE (maximum): 10 volts rms open circuit; 10 volts rms across a 1,000 ohm load; 6 volts rms across a 600 ohm load (with reduced setting of the RMS VOLTS control).

AMPLITUDE: Constant within ±0.25 db over the frequency range from 1.0 cps to 10 kc, within ±0.75 db from 0.01 cps to 100 kc, within ±3 db from 0.001 cps to 0.01 cps at constant line voltage; within ±0.05 db for a ±10% change in line voltage at any frequency.

IMPEDANCE: Nominal 1,000 ohms at the five volt position of the RMS VOLTS control; impedance drops to a very low value at either end of this control.

CONTROL: Potentiometer labelled RMS VOLTS calibrated logarithmically in rms volts, open circuit, from 0.01 to 10.

CIRCUIT: Direct coupled from the cathode follower output stage of a feedback loop through the RMS VOLTS control.

DC COMPONENT: Nominal zero volts.

HARMONIC DISTORTION: Less than 0.1% at any output level setting over the frequency range from 4 cps to 10 kc, rising to 3% at 0.02 cps and 100 kc, and approximately 10% at 0.001 cps.

MINIMUM LOAD IMPEDANCE: 1,000 ohms for rated distortion when the output control is set at maximum; at lower settings lower impedance loads may be used without exceeding rated distortion.

HUM LEVEL: Less than 0.1% at any output level setting.

SQUARE WAVE OUTPUT:

VOLTAGE: 10 volts peak to peak open circuit; approximately 5 volts peak to peak across a 1,500 ohm load.

AMPLITUDE: Constant within ±1% over the entire frequency range from 0.001 cps to 100 kc at constant line voltage; within ±1% for a ±10% change in line voltage at any frequency.

INTERNAL IMPEDANCE: Nominal 1,500 ohms.

MINIMUM LOAD IMPEDANCE: 1,500 ohms for an output of 5 volts peak to peak; lower values of load impedance will reduce output voltage without deteriorating performance.

CONTROL: The square wave output is fixed; no control for varying the amplitude is provided.

CIRCUIT: Direct coupled from two cascaded multi-vibrators triggered by the sine wave.

DC COMPONENT: Nominal zero volts.
SQUARE WAVE SPECIFICATIONS: Rise time less than 0.5 microsecond; symmetrical within ±8%; flat top with no appreciable droop or overshoot at any frequency; positive and negative half cycle amplitude symmetrical about zero within ±10%.

CONTROLS:
FREQUENCY MULTIPLIER switch.
FREQUENCY CPS push buttons.
FREQUENCY VERNIER control.
RMS VOLTS control.
POWER OFF-ON switch.

TERMINALS: Two multi-purpose binding posts for the SINE WAVE OUTPUT and two for the SQUARE WAVE OUTPUT; each output has a parallel BNC type connector in the rear of the chassis.

POWER REQUIREMENTS:
105-125/210-250 volts, single phase, 50-400 cycles, 120 watts.

FUSE PROTECTION:
2 ampere slow-blow, for 105-125 volt operation
1 ampere slow-blow, for 210-250 volt operation.

FORM: Furnished in an attractively styled sturdy cabinet. Front panel finished in gray enamel, and cabinet in blue enamel. Other finishes available on special order. Dimensions Model 440A: 17" wide, 8" high, 12" deep. Weight 37 lbs. net, 42 lbs. shipping. Dimensions Model 440AR: 19" wide, 8-3/4" high, 12" deep. Weight 38 lbs. net, 44 lbs. shipping.

SECTION 2

OPERATING INSTRUCTIONS

2.1 GENERAL

On receipt of the Oscillator, carefully unpack and examine it for any damage that may have occurred in transit. If the Oscillator has been damaged in any way, immediately file a claim with the transporting agency and then notify Krohn-Hite Corporation.

The Model 440A(R) PUSH-BUTTON OSCILLATOR is checked carefully in Final Test to ensure that the Oscillator meets all its specifications. It is operated continuously for not less than 48 hours and again tested prior to shipment to ensure that the instrument is ready for use. The Oscillator is easy to operate and requires no initial adjustment.

The desired frequency is selected by the three banks of ten push-button switches and reads directly in cycles per second when the FREQUENCY VERNIER control is turned maximum clockwise to the "OFF" position. This control varies the frequency continuously by an amount equal to the increment between adjacent buttons of the third switch bank with additional frequency overlap beyond 10 on the vernier dial. Frequencies between .01 cps and 1 cps

are obtained by setting the first, or first and second banks of push-buttons, to zero. For frequencies between .001 cps and .01 cps set all three banks of push-buttons to zero and use vernier control to select frequency. For maximum frequency accuracy the first row of push-button switches should not be set to zero except when requiring frequencies below 1 cps. The FREQUENCY MULTIPLIER switch selects the proper multiplying factor for the five bands.

The sine wave RMS VOLTS control is logarithmically tapered and adjusts the level of the sine wave output as read directly in rms volts on the calibrated scale. This scale indicates the approximate unloaded output.

A minimum load of 1,000 ohms is specified to ensure low distortion when the RMS VOLTS control is at or near the maximum setting. A lower impedance load will not damage the instrument. When the RMS VOLTS control is operated at reduced level a lower impedance may be used without increasing the distortion.

The square wave output is constant and provides 10 volts peak to peak. Since the rise time of the square wave improves as the impedance across its output decreases, the amplitude of the square wave can be varied most efficiently by shunting the proper resistance directly across the square wave output terminals.

2.2 OPERATING PROCEDURE

2.2.1 TURNING ON THE OSCILLATOR

a. Plug the power line cord into the appropriate ac power source (refer to Section 2.2.3).

b. Turn the power switch to the "ON" position. The pilot lamp will light.

c. Allow the oscillator to warm up for at least 15 minutes.

2.2.2 SELECTING A FREQUENCY

a. Depress one push-button in each of the three rows of push-buttons.

b. Turn the FREQUENCY MULTIPLIER switch to the desired multiplication factor.

c. Adjust the FREQUENCY VERNIER control for fourth figure accuracy. When the FREQUENCY VERNIER control is turned maximum counter clockwise to the "OFF" position, the FREQUENCY CPS push-button switches read directly in cps times the multiplying factor which is selected by the FREQUENCY MULTIPLIER switch.

NOTE

The Oscillator will not operate unless <u>one</u> button in <u>each</u> one of three rows of FREQUENCY CPS switches is depressed. For maximum frequency accuracy, zero should not be set in the first row of push-button switches (left-hand row).

EXAMPLE: 10 cps could be set by entering 0, 1, 0, (from left to right), and setting the FREQUENCY MULTIPLIER switch to the "1" position. However, for maximum frequency accuracy, 10 cps should be set by entering 1, 0, 0, (from left to right), and setting the FREQUENCY MULTIPLIER switch to the ".1" position.

2.2.3 LINE VOLTAGE

The Oscillator, as normally shipped, is wired for operation from an a-c power source of 105 to 125 volts, 50 to 400 cycles, and uses a 2 ampere slow-blow line fuse. The Oscillator may be modified to operate from an a-c power source of 210 to 250 volts by removing the two jumpers on the 4 terminal barrier strip (located underneath the chassis adjacent to the power transformer) between terminals 1 and 2 and between 3 and 4 and by adding a jumper between terminals 2 and 3. A one (1) ampere slow-blow line fuse should be used for 210-250 volt operation.

SECTION 3

THEORY OF OPERATION

There are two essential requirements that must be realized in any oscillator in order to generate low distortion oscillations with constant amplitude. The internal loop gain* must be positive or regenerative with zero phase shift at the frequency of oscillation and at this frequency the gain must be precisely equal to unity.

If the internal loop gain is greater than unity by any finite amount, the amplitude of oscillation will build up until it saturates the amplifier. When the internal loop gain is less than unity the amplitude of oscillation will diminish to zero.

If the phase shift in the amplifier at the resonant frequency deviates from zero, the frequency of oscillation will no longer be determined entirely by the RC network parameters. Since the requirements for zero phase shift must be maintained in the internal loop, the frequency of oscillation will be "pulled" to satisfy the necessary conditions of zero phase shift.

This frequency "pulling" is minimized by using high gain wide band amplification to provide a steep rate of change of phase shift about the resonant frequency.

For the purpose of circuit analysis the simplified circuit diagram of the Oscillator, as shown in Figure 2, applies.

*The internal loop gain of the oscillator as shown in the simplified circuit diagram in Figure 2 is the voltage amplitude at point A when the loop is opened between A and B and unit voltage impressed at B.

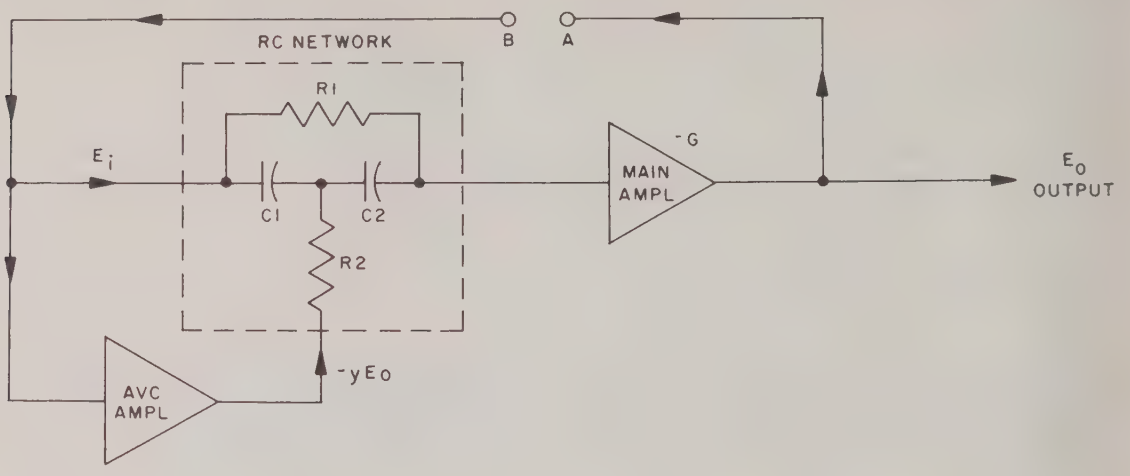

Figure 2. Simplified Circuit Diagram

If the internal loop is broken between A and B, and a unit voltage E_i is impressed at B, the internal loop gain is given by the following equation:

$$\frac{E_o}{E_i} = -G \frac{p^2R_1R_2C_1C_2 + p(R_2C_1 + R_2C_2 - yR_1C_2) + 1}{p^2R_1R_2C_1C_2 + p(R_2C_1 + R_2C_2 + R_1C_2) + 1} \quad (1)$$

Where -G represents the gain of the amplifier and $p = j\omega$.

In the Model 440A(R), $C_1 = C_2$ and $R_1 = 10R_2$. Thus $R_1C_1 = 10R_2C_2 = 10R_2C_1$. If $R_1C_1R_2C_2 = T^2$, it can be shown that $R_1C_1 = T\sqrt{10}$ and $R_2C_2 = T/\sqrt{10}$.

By substitution into equation (1) the following equation is obtained:

$$\frac{E_o}{E_i} = -G \frac{p^2T^2 + \sqrt{10}\,pT\,(.2 - y) + 1}{p^2T^2 + \sqrt{10}\,pT\,(1.2) + 1} \quad (2)$$

The internal loop phase and amplitude response versus frequency for this circuit is shown in Figure 3. At the high and low frequencies the gain levels off to -G. Where $(\omega T)^2 = 1$, or $(\omega = 1/T)$ the gain dips to a minimum value.

From the curve of phase angle versus frequency it can be seen that for the frequency of oscillation (f_o) the phase shift is 0^o and for higher and lower frequencies the phase shift becomes 180^o, thereby giving degeneration of the higher harmonics and regeneration of the fundamental. At the frequency of oscillation (f_o where $\omega = 1/T$) equation (2) reduces to:

$$\frac{E_o}{E_i} = -G \frac{.2 - y}{1.2} \quad (3)$$

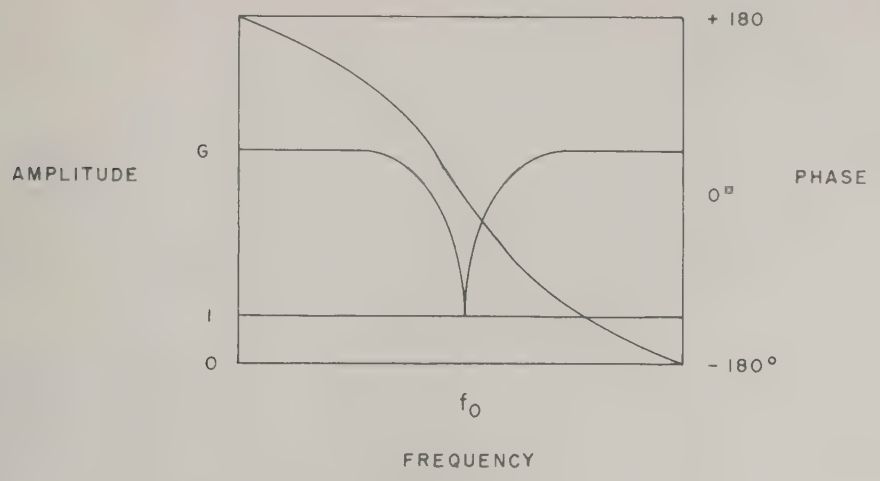

Figure 3. Open Loop Phase and Amplitude Response

To satisfy the essential requirements of an oscillator, equation (3) must be precisely equal to unity and E_o must be in phase with E_i. If $y = .2 + 1.2/G$ equation (3) reduces to unity. The phase relationship is satisfied by using an odd number of stages of amplification which is required for harmonic degeneration and making y greater than 0.2.

The AVC amplifier and the voltage sensitive device (I101 in series with I102) maintain equation (3) equal precisely to unity, independent of variations in the internal loop gain by maintaining $y = .2 + 1.2/G$. The voltage sensitive device uses tungsten elements of small incandescent bulbs whose resistances are proportional to the dissipated power. Since the power across the series elements is obtained directly from the oscillator output, the resistance is proportional to the amplitude of oscillation. If the series elements are the only voltage sensitive devices in the AVC circuit, the amplitude of oscillation must adjust itself until equation (3) is precisely equal to unity.

The operation of the AVC amplifier and the voltage sensitive device may be understood more easily, for example, if we assume that the output amplitude E_o of the Oscillator decreases due to a decrease in the gain, G, of the main amplifier. This results in a proportional decrease in the signal at the grid of V1A. The signal at the grid of V1B will decrease more than the one at V1A because the resistances of the voltage sensitive series elements, I101 and I102, will decrease with decreasing voltage. The error voltage, resulting from this differential decrease in amplitude, is amplified by the AVC amplifier and increases the output of the AVC amplifier, $-y E_o$. This error voltage appearing at the output of the AVC amplifier restores the amplitude to approximately its original level.

The amplitude must decrease slightly below its original level to provide an incremental decrease in the resistance of the tungsten series elements. This restores the internal loop gain to unity by increasing y to compensate for the decrease in gain, G, of the main amplifier.

SECTION 4

CIRCUIT DESCRIPTION

4.1 POWER SUPPLIES

The Model 440A(R) has three power supplies - one unregulated supply and two electronically regulated supplies. The UNREGULATED SUPPLY uses a full-wave rectifier tube V9 whose output is filtered by a capacitor input single section pi filter consisting of C401, C402, and L401.

One electronically regulated supply, consisting of tubes V10, V11 and V12 and referred to as the REGULATED SUPPLY, provides 350 volts regulated. The other electronically regulated supply, consisting of tubes V13 and V14 and referred to as the CENTER-TAP REGULATOR, divides the 350 volts into two balanced or equal positive and negative supplies, +175 and -175 volts with respect to ground.

The REGULATED SUPPLY functions in a conventional manner in that the cathode of the first amplifier tube, V11B is held constant by V12 at approximately -85 volts with respect to chassis ground. Variations due to changes in line voltage and load changes are reduced by coupling the negative side of the unregulated supply (normally -175 volts with respect to chassis ground) to the grid of the first amplifier V11B. The output of V11B is amplified in V11A and coupled to the grid of V10 in a manner to reduce the effect of an input or output disturbance.

The CENTER-TAP REGULATOR adds the negative and positive of the 350 volt REGULATED SUPPLY through two equal resistors R410 and R413 and compares their sum with chassis ground in the differential amplifier V13. Since the comparison resistors are equal and the reference voltage is chassis ground the regulated 350 volts is divided into two balanced or equal and opposite voltages, +175 and -175 volts with respect to ground. The output of V13 is coupled to V14 which acts as a variable resistance to compensate for load variations in either the +175 or -175 volt busses.

4.2 MAIN AMPLIFIER

The main amplifier, consisting of tubes V5, V6, V7 and V8, sustains the oscillations at the frequency determined by the RC network and provides the gain necessary for harmonic degeneration.

The output of the RC network is fed to the first stage of the main amplifier V5B. A balanced input amplifier is used in the first stage to reduce drift in the d-c output level with variations in line voltage. Another cathode coupled amplifier consisting of V6 and V7 provides the additional gain necessary to maintain the specified distortion and amplitude constancy. The second amplifier drives the output amplifier V8 which operates as a cathode follower to deliver the rated power output.

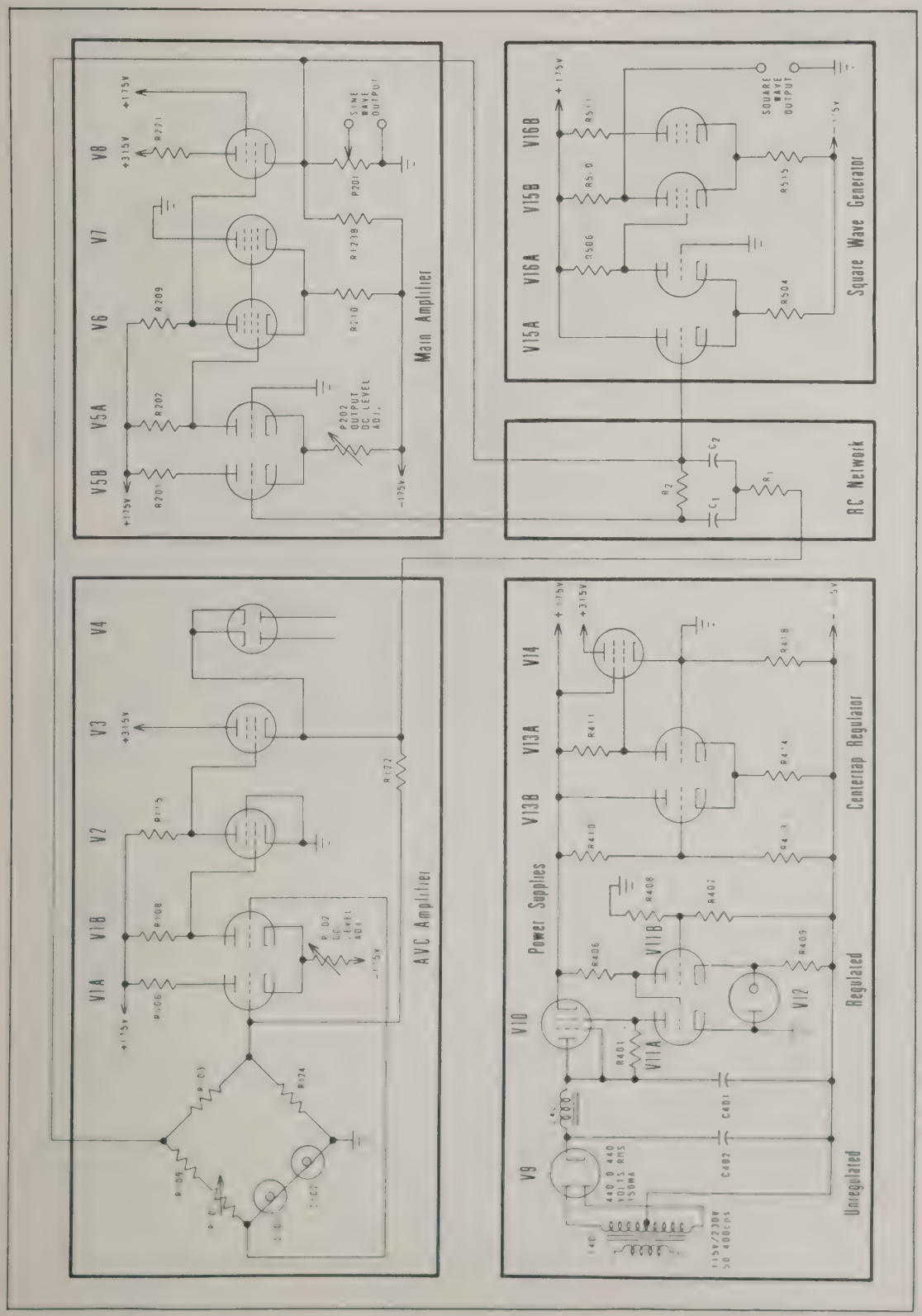

Figure 4. Simplified Schematic

4.3 AVC AMPLIFIER

The AVC amplifier, consisting of tubes V1, V2, V3, and V4, maintains the amplitude of oscillation very nearly constant independent of frequency. The operation of the AVC amplifier can be understood more easily by referring to the simplified block diagram, Figure 4.

The basic amplitude discriminator is a bridge whose four resistance arms consist of R103, R124, R101 in series with R109, and I101 & I102 (two tungsten filament lamps operating as a voltage sensitive device). The bridge is driven from the output of the main amplifier, and the output of the bridge is amplified in the differential input amplifier, V1.

A second stage of amplification, V2, provides the additional gain required to maintain low distortion. The output of V2 drives the output amplifier V3, which functions as a cathode follower to maintain the AVC signal at its required impedance level. The overall gain of the AVC amplifier is maintained very nearly constant by feeding back degeneratively a portion of the output signal via R122 to the input amplifier V1. Additional AVC action is provided by V4 when excessive signals are encountered in the AVC amplifier.

4.4 SQUARE WAVE GENERATOR

The square wave generator consists basically of two multivibrators operating in series. One triode multivibrator, consisting of tubes V15A and V16A, is triggered directly from the sine wave output of the Oscillator. The triode multivibrator is designed primarily to trigger easily and supply the required trigger for the pentode multivibrator. It does not have a fast rise time to provide a satisfactory square wave output. The pentode multivibrator, which consists of tubes V15B and V16B, is triggered from the output of the triode multivibrator. A suitable square wave output is obtained directly from the plate of V15B.

SECTION 5

SIMPLIFIED MAINTENANCE

If the oscillator is not functioning properly and requires maintenance the following procedure in the order described may facilitate locating the source of trouble.

The chassis will slide out through the front of the cabinet by removing the four slotted thumb screws on the front panel and the two machine screws on the bottom of the cabinet.

a. If the Oscillator blows fuses replace the rectifier tube and if necessary check for shorts in the unregulated and regulated voltage busses and the 4 MFD filter capacitors C401 and C402.

b. Turn on the Oscillator and then make certain that the correct tubes are inserted properly in their respective sockets. At the same time see if the filaments of the glass tubes are lighted and if the metal ones are warm. If any of the tube filaments fail to light or the metal tubes are not warm after sufficient warm-up time, replace them.

c. If the above procedure produces no results the likeliest source of failure is the vacuum tubes. Obtain appropriate new tubes and then one at a time, substitute the new tube in each position in the Oscillator where it is used.

d. Check the regulated supply voltages, which should be +175 ±5 volts and -175 ±5 volts. The +175 volt regulated buss can be checked at the cathode of V10; the -175 volt regulated buss at the negative terminal of the 4 MFD filter capacitors, C401 or C402. If these voltages are incorrect check the wiring and take resistance and voltage readings to ground on tubes V9 through V14. These magnitudes are given in Figure 9.

e. Measure the output d-c level of the main amplifier at the cathode of V8. It should be zero ±1 volt. If this level is incorrect adjust the output d-c level control P202 at the rear of the chassis. If this does not restore the level to its proper value check the wiring associated with tubes V5, V6, V7, and V8 and if necessary take resistance and voltage readings to ground. Refer to Figure 9.

f. Measure the output d-c level of the AVC amplifier at the cathode of V3. It should be zero ±1 volt. If this level is incorrect adjust the AVC amplifier d-c level control P102 at the rear of the chassis. If this does not restore the level to its proper value check the wiring associated with tubes V1, V2, V3, and V4 and if necessary take resistance and voltage readings to ground. Refer to Figure 9.

g. Check the resistances of the tungsten filament lamps located on the underside of the chassis. Each should measure between 200 and 400 ohms. If they are defective see "Tube Complement Check," Section 6.1.

h. If the Oscillator works properly on some bands but not on others, or the frequency calibration deviates from its indicated value, the frequency determining parameters may be defective. Refer to "RC Network Calibration," Section 6.6.

SECTION 6

CORRECTIVE MAINTENANCE

NOTE

The Corrective Maintenance procedure has been outlined in great detail because localizing a malfunction in oscillators containing multi-loop feed back amplifiers can often be time consuming. The SIMPLIFIED MAINTENANCE procedure in Section 5 is recommended at first because it is easier to use and has sufficient information to localize most operational failures in a relatively short time.

6.1 TUBE COMPLEMENT CHECK

Before any maintenance procedure, turn on the Oscillator and check to make certain the correct tubes are inserted properly in their respective sockets as shown in the top view in Figure 6. At the same time note if the filaments of the glass tubes are lighted and feel if the metal ones are warm. If any of the tube filaments fail to light or the metal tubes are not warm after sufficient warm-up time, replace them.

If the above procedure produces no results the likeliest source of failure is the vacuum tubes since they have an inherently shorter life. Obtain appropriate new tubes and then one at a time, substitute the new tube in each position in the Oscillator where it is used. The type number of each tube is marked on the chassis adjacent to the tube.

The AVC elements, I101 and I102 may be checked by removing them from their sockets and connecting an ohmmeter across their contacts. A resistance less than 200 ohms or greater than 400 ohms probably indicates a defective element.

If any difficulty is experienced in obtaining a replacement, write to our Factory Service Department. If it is necessary to substitute a new element, the setting of P101 may have to be changed. To check this, set the sine wave RMS VOLTS control on the panel to 10 volts and measure the voltage across the output terminals with a high impedance meter or oscilloscope. Adjust P101 to obtain an output of 10 volts rms.

6.2 FUSE FAILURE

A 1 or 2 ampere (slow-blow) cartridge fuse, located in the back of the chassis, is used in the primary circuit of the power transformer to protect the power supply components from short circuits. The rating of the fuse was selected for proper protection of the instrument and should be replaced with the same type and rating. Refer to Section 2.2.3.

If a fuse failure is detected the following procedure is recommended before replacing the fuse:

a. Remove the rectifier tube, V9, and disconnect the power cord. Measure the d-c primary resistance of the power transformer which should be 2.3 ohms for 105-125 volt operation or 9.2 ohms for 210-250 volt operation. A lower resistance probably indicates a shorted primary.

b. Insert a new fuse, connect the power, and then check the primary and secondary voltages of the transformer. If the voltages are correct the transformer is functioning properly and the fuse failure is probably due to either a faulty rectifier tube, a short circuit in one of the 4 MFD filter capacitors, C401 or C402, or a short circuit in the +330* volt unregulated buss or the +175 and -175 volt regulated busses.

*The +330 volt buss is a voltage referred to ground and not to the center tap of the high voltage secondary which is normally at -175 volts with respect to ground.

c. Prior to inserting a new rectifier tube disconnect the power and check the 4 MFD filter capacitors C401 and C402. A shorted capacitor can be detected by connecting an ohmmeter (low range) across it directly. If these capacitors are not shorted, check the regulated and unregulated busses to determine if they are shorted to each other or individually to ground. The +330 unregulated buss can be located conveniently at the plate of V10. The +175 volt regulated buss can be checked at the cathode of V10 and the -175 volt regulated buss at the negative terminal of the 4 MFD filter capacitors, C401 or C402.

d. If the above procedure has not uncovered any faulty components or wiring, the rectifier tube may be the cause of the trouble and should be replaced.

In most cases the above procedure will uncover the cause of a fuse failure. However, occasions arise when unusual defects occur like intermittent shorts in components and tubes, and short circuits resulting from foreign particles. These unfortunately, are beyond the scope of this maintanence procedure.

6.3 POWER SUPPLIES

If the Oscillator is not functioning when the rated line voltage is applied and the instrument is powered as indicated by the pilot light or visible tube filaments, it is advisable to check the power supplies.

The Model 440A(R) has three power supplies - one unregulated supply and two electronically regulated supplies. One electronically regulated supply, referred to as the REGULATED SUPPLY, provides 350 volts regulated.

The other electronically regulated supply, referred to as the CENTER-TAP REGULATOR, divides the 350 volt REGULATED SUPPLY into two equal voltages +175 and -175 volts with respect to ground.

6.3.1 CENTER-TAP REGULATOR

When the center-tap regulator is not functioning properly, it may upset the normal operation of the regulated and unregulated supplies and therefore, should be checked first.

The center-tap regulator adds the positive and negative voltages of the regulated supply through equal adding resistors R410 and R413, and compares the sum with chassis ground in the differential amplifier V13.

It is worth emphasizing again that the center-tap regulator divides the regulated supply into two balanced voltages. Under normal conditions the regulated supply delivers 350 volts, which is balanced by the center-tap regulator into two voltages +175 and -175 volts with respect to chassis ground. If the regulated supply puts out 300 volts instead of the normal 350 volts, the center-tap regulator, if functioning properly will divide the 300 volts into two equal and opposite voltages +150 and -150 volts with respect to chassis ground. When the output of the center-tap regulator is balanced, irrespective of the magnitude of the voltages, the center-tap regulator is functioning properly.

If the regulated positive and negative supplies are appreciably unbalanced, their sum as measured at the grid of V13B will not be zero if the additive resistors R410 and R413 are correct. The additive resistors should be checked first by measuring the resistance between the grid of V13B and the +175 and -175 volt busses. Equal resistance readings measured with the Oscillator turned off, indicates that the additive resistors are the correct value.

When the center-tap regulator is unbalanced and the magnitude of the regulated negative supply is greater than the regulated positive supply, the grid of V13B which is normally at zero volts will be more negative. This decreases the current in V13B and increases the current in V13A. The plate of V13A, which is normally at +120 volts, should be less positive because of the increased plate current. If the plate of V13A is not appreciably less positive than normal when the output of the regulated negative supply is greater than that of the regulated positive supply, V13 is not functioning properly and its wiring, components, voltage readings and resistance readings to ground should be checked.

When the plate of V13A is appreciably less positive than normal, the grid of V14, which is normally at -7 volts, should be more negative. If the grid of V14 is not appreciably more negative than normal, check the components, wiring and resistance readings associated with the grid of V14.

When the grid of V14 is more negative than normal the plate current in V14 will decrease and should balance the positive and negative regulated supplies.

When the center-tap regulator remains unbalanced even though the grid of V14 is more negative than normal, the trouble may be due to a malfunction not originating in the center-tap regulator. An excessive unbalance in the current drain due to a malfunction in the main or AVC amplifier can prevent the center-tap regulator from operating properly. Under this condition, since the operating voltages are incorrect, the main and AVC amplifier can be tested only by checking their resistance readings to ground. See "Main Amplifier," Section 6.4, and "AVC Amplifier," Section 6.5, and Figure 9 for resistance readings to ground.

When the center-tap regulator is unbalanced and the magnitude of the regulated positive supply is greater than the regulated negative supply, the grid of V13B which is normally at zero volts will be more positive. This increases the current in V13B and decreases the current in V13A. The plate of V13A, which is normally at +120 volts, should be more positive because of the decreased plate current. If the plate of V13A is not appreciably more positive than normal when the regulated positive supply is greater than the regulated negative supply, V13 is not functioning properly and its components, wiring, voltage readings and resistance readings to ground should be checked.

When the plate of V13A is appreciably more positive than normal the grid of V14, which is normally at -7 volts, should be less negative. If the grid of V14 is not appreciably less negative than normal, check the components, wiring and resistance readings associated with the grid of V14.

When the grid of V14 is less negative than normal the plate current of V14 will increase and should balance the positive and negative regulated supplies.

When the center-tap regulator remains unbalanced even though the grid is less negative than normal, the trouble may be due to a malfunction not originating in the center-tap regulator. An excessive unbalance in the current drain due to a malfunction in the main or AVC amplifier can prevent the center-tap regulator from operating properly. Under this condition, since the operating voltages are incorrect, the main and AVC amplifier can be tested only by checking their resistance readings to ground. See "Main Amplifier," Section 6.4, and "AVC Amplifier," Section 6.5, and Figure 9 for resistance readings to ground.

6.3.2 UNREGULATED SUPPLY

The +330 volt unregulated supply voltage, as derived from the cathode of the rectifier tube V9, is filtered in a capacitor input single-section pi filter consisting of C401, C402, and L401. The unregulated voltage should be checked at rated line voltage, bearing in mind that the voltage is referred to chassis which is ground potential.

If the unregulated voltage deviates from its proper value, replace the rectifier, V9. When replacing V9 brings about no change in the voltage level, check the total current drain by measuring the voltage across L401 which under normal conditions should measure 20 volts. If this voltage is appreciably higher than normal the Oscillator is drawing excessive current. The excessive current may be due to a low resistance path which can occur in the 4 MFD filter capacitor C402 or in the Oscillator when the output d-c levels of the main amplifier and AVC amplifier are incorrect. See "Main Amplifier," Section 6.4, and "AVC Amplifier," Section 6.5.

6.3.3 REGULATED SUPPLY

Under normal conditions the regulated supply delivers 350 volts, which is balanced by the center-tap regulator into two voltages +175 and -175 volts with respect to ground. If the regulated supply is not delivering its rated voltage, the values and wiring of the two voltage level determining resistors R407 and R408 should be checked first.

When the voltage output of the regulated supply is greater than its normal voltage of 350 volts or +175 and -175 volts to ground, the cathode of V11B should maintain its normal voltage of approximately -85 volts because of the action of the voltage regulator tube V12. The voltage between the grid and cathode of V11B which is normally 3.5 volts will be more negative because of the increased voltage of the negative supply. This decreases the plate current in V11B and increases the plate voltage, which is normally at +110 volts, to a more positive value. If the plate of V11B is not appreciably more positive than normal, V11B is not functioning properly and its components, wiring, voltage readings and resistance readings to ground should be checked.

If the plate of V11B is appreciably more positive than normal, the grid of V11A should be less negative than normal. This should increase the plate current in V11A and decrease the plate voltage of V11A, which is normally at +155 volts, to a less positive value. If the grid of V11A is not appreciably less negative or the plate of V11A is not appreciably less positive than their normal values, V11A is not functioning properly and its components, wiring, voltage readings and resistance readings to ground should be checked.

If the plate of V11A is less positive than normal, the grid of V10 should also be less positive than normal, since the tubes are direct coupled through the parasitic suppressor resistor R402. If the grid of V10 is not approximately at the same voltage as the plate of V11A, check the components and wiring associated with the grid of V10.

When the grid of V10 is appreciably less positive than normal, the plate current will decrease. This increases the plate to cathode voltage of V10 and should restore the regulated supply to its proper voltage.

When the voltage of the regulated supply is lower than its normal value of 350 volts, or +175 and -175 volts to ground, the cathode of V11B should maintain its normal voltage of approximately -85 volts, provided the negative supply voltage does not drop below the voltage necessary to fire the voltage regulator tube V12. The voltage between the grid and cathode of V11B which is normally 3.5 volts, will be less negative because of the decreased voltage of the negative supply. This increases the plate current in V11B and should lower the plate voltage which is normally at +110 volts to a much lower value. If the grid of V11B is not appreciably more positive or the plate of V11B is not appreciably less positive than their normal values, V11B is not functioning properly and its components, wiring, voltage readings and resistance readings to ground should be checked.

When the plate of V11B is appreciably less positive than its normal value, the grid of V11A, which is normally at -2 volts, should be more negative. This causes the plate current in V11A to decrease and should raise the plate voltage which is normally at +155 volts to a more positive value. If the grid of V11A is not appreciably more negative or the plate is not appreciably more positive than their normal value, V11A is not functioning properly and its components, wiring, voltage readings and resistance readings to ground should be checked.

When the plate of V11A is appreciably more positive than normal, the grid of V10 should also be more positive than normal, since the tubes are direct coupled through the parasitic suppressor resistor R402. If the grid of V10 is not approximately at the same voltage as the plate of V11A, check the components and wiring associated with the grid of V10.

When the grid of V10 is more positive than normal, the plate current will increase. This decreases the plate to cathode voltage of V10 and should restore the regulated supply to its proper voltage.

6.4 MAIN AMPLIFIER

Under normal conditions the output d-c level of the main amplifier should be zero ±1 volt as measured at the cathode of V8, or at the sine wave output terminals when the sine wave amplitude control is set at maximum output. A potentiometer P202 is available at the rear of the chassis to adjust this output d-c level. The output d-c level is maintained at this value because it is compared with ground in the differential amplifier V5. The grid of V5A is connected to ground and the grid of V5B is connected via the RC network to the output of the main amplifier V8.

There are two likely malfunctions that might occur outside the main amplifier that would result in an incorrect output d-c level even though the main amplifier is functioning properly. When the sine wave output is excessively distorted or the d-c path in the RC network is interrupted, the output d-c level of the main amplifier will differ from its normal value. Before checking the main amplifier it is advisable to eliminate the possibility of these two malfunctions. Excessive sine wave amplitude can be eliminated by stopping the Oscillator from functioning. Switch the frequency multiplier control to band 5, set the frequency to 10,000 cps., and connect a 0.1 MFD capacitor from the control grid of V8 to ground. If the output d-c level returns to its normal value, zero ±1 volt, the level determining components in the main amplifier are functioning properly and the trouble is probably in the AVC amplifier, which is described in "AVC Amplifier," Section 6.5. If the output d-c level does not return to its proper value, check the possibility of an open circuit in the d-c path of the RC network. Short circuit the RC network by connecting a jumper from the output of the main amplifier (cathode of V8) to the input of the main amplifier (grid of V5B). Check the output d-c level of the main amplifier with the jumper and the 0.1 MFD capacitor connected. If the level returns to its normal value, this indicates a malfunction in the RC network. The procedure for checking the RC network is described in "RC Network Calibration," Section 6.6. If the output d-c level does not return to its normal value when the jumper is connected, the main amplifier is not functioning properly. Remove the jumper but leave the 0.1 MFD capacitor connected as before.

If the output d-c level of the main amplifier is appreciably more positive than normal, the grid of V5B will be more positive than normal. This increases the plate current in V5B and decreases the plate current in V5A. The plate of V5A, which is normally at +110 volts, should be more positive because of the decreased plate current. If the plate of V5A is not appreciably more positive than normal, when the output d-c level of the main amplifier is excessively positive, V5 is not functioning properly and its wiring, components, voltage readings and resistance readings to ground should be checked.

If the plate of V5A is appreciably more positive than normal, the grid of V6 should be less negative than normal. This should increase the plate current in V6 and decrease the plate current in V7. The increased plate current of V6 should decrease the plate of V6, which is normally at +105 volts, to a less positive value. If the grid of V6 is not appreciably less negative or the plate of V6 is not appreciably less positive than normal, V6 or V7 are not functioning properly and their wiring, components, voltage readings and resistance readings to ground should be checked.

When the plate of V6 is appreciably less positive than normal, the grid of V8 should be more negative than normal. If the grid of V8 is not appreciably more negative than normal, check the wiring, components and resistance readings associated with the grid of V8. When the grid of V8 is more negative than normal, the plate current will decrease and should restore the output d-c level of the main amplifier to its proper voltage.

When the output d-c level of the main amplifier is appreciably more negative than normal, the grid of V5B will be more negative than normal. This decreases the plate current in V5B and increases the plate current in V5A.

The plate of V5A, which is normally at +108 volts, should be less positive because of the increased plate current. If the plate of V5A is not appreciably less positive than normal when the output d-c level of the main amplifier is excessively negative, V5 is not functioning properly and its wiring, components, voltage readings and resistance readings to ground should be checked.

When the plate voltage of V5A is appreciably less positive than normal, the grid of V6 should be more negative than normal. This should decrease the plate current in V6 and increase the plate current in V7. The decreased plate current of V6 should increase the plate of V6, which is normally at +105 volts to a more positive value. If the grid of V6 is not appreciably more negative than normal or the plate is not appreciably more positive than normal, V6 or V7 is not functioning properly, and their wiring, components, voltage readings and resistance readings to ground should be checked.

When the plate of V6 is appreciably more positive than normal, the grid of V8 should be more positive than normal. If the grid of V8 is not appreciably more positive than normal, check the wiring, components and resistance readings associated with the grid of V8.

When the grid of V8 is more positive than normal the plate current will increase and should restore the output d-c level of the main amplifier to its proper value.

If the Oscillator exhibits a tendency to generate spurious signals or does not function properly on the high frequency ranges, the high frequency by-pass capacitors in the main amplifier, C201 through C210, may be open and should be checked. This can be done by disconnecting them and measuring them directly, or more easily by shunting a capacitor of the same value across them directly without removing the capacitor in the instrument. If the performance of the Oscillator changes appreciably when a capacitor is by-passed, the capacitor is probably defective and should be replaced.

6.5 AVC AMPLIFIER

Under normal conditions the output d-c level of the AVC amplifier should be zero ±1 volt as measured at the cathode of V3. A test point and potentiometer P102 are provided at the rear of the chassis to adjust this output d-c level. Since the bridge on the input of the AVC amplifier is direct coupled to the output of the main amplifier, it is important that the output of the main amplifier be at its correct d-c level before checking the output d-c level of the AVC amplifier. To eliminate the possibility of introducing an unwanted signal into the AVC amplifier which may upset the output d-c level, it is desirable that a 0.1 MFD capacitor be connected from the grid of output amplifier V8 to ground. The frequency multiplier control should be switched to band 5 and the Oscillator should be set at a frequency of 10,000 cps.

If the output d-c level of the AVC amplifier is appreciably more positive than normal, the grid of V1A will be less negative than normal. This increases the plate current in V1A and decreases the plate current in V1B. The plate of V1B, which is normally at +110 volts, should be more positive because of the decreased plate current. If the plate of V1B is not appreciably more

positive than normal when the output d-c level of the AVC amplifier is excessively positive, V1 is not functioning properly and its wiring, components, voltage readings and resistance readings to ground should be checked.

If the plate of V1B is appreciably more positive than normal, the grid of V2 should be less negative than normal. This should increase the plate current in V2 and decrease the plate voltage, which is normally at +140 volts, to a less positive value. If the grid of V2 is not appreciably less negative or the plate of V2 is not appreciably less positive than normal, V2 is not functioning properly and its wiring, components, voltage readings and resistance readings to ground should be checked.

When the plate of V2 is appreciably less positive than normal, the grid of V3 should be more negative than normal. If the grid of V3 is not appreciably more negative than normal, check the wiring, components and resistance readings associated with the grid of V3. When the grid of V3 is more negative than normal, the plate current will decrease and should restore the output d-c level of the AVC amplifier to its proper voltage.

When the output d-c level of the AVC amplifier is appreciably more negative than normal, the grid of V1A will be more negative than normal. This decreases the plate current in V1A and increases the plate current in V1B. The plate of V1B, which is normally +110 volts, should be less positive because of the increased plate current. If the plate of V1B is not appreciably less positive than normal when the output d-c level of the AVC amplifier is excessively negative, V1 is not functioning properly and its wiring, components, voltage readings and resistance readings to ground should be checked.

When the plate of V1B is appreciably less positive than normal, the grid of V2 should be more negative than normal. This should decrease the plate current of V2 and increase the plate voltage, which is normally at +140 volts, to a more positive value. If the grid of V2 is not appreciably more negative than normal or the plate is not appreciably more positive than normal, V2 is not functioning properly, and its wiring, components, voltage readings and resistance readings to ground should be checked.

When the plate of V2 is appreciably more positive than normal, the grid of V3 should be more positive than normal. If the grid of V3 is not appreciably more positive than normal, check the wiring, components and resistance readings associated with the grid of V3.

When the grid voltage of V3 is more positive than normal, the plate current will increase and should restore the output d-c level of the main amplifier to its proper voltage.

If the Oscillator exhibits a tendency to generate spurious signals or does not function properly on the high frequency ranges, the high frequency by-pass capacitors, C101 to C106, in the AVC amplifier, may be open circuited and should be checked. This can be done by disconnecting them and measuring them directly, or more easily by shunting a capacitor of the same value across them directly without removing the capacitor in the Oscillator. If the performance of the Oscillator changes appreciably when a capacitor is by-passed, the capacitor is probably defective and should be replaced.

6.6 RC NETWORK CALIBRATION

If the Oscillator is operating erratically on some bands or the frequency calibration deviates from its indicated value, the frequency multiplier band switch, the push-button switches or the frequency determining parameters of the network may be defective. Adjust C102 if the high frequency calibration at 100 kc is incorrect. If the contacts on all the switches are excessively dirty, direct a stream of compressed air at them and then check each contact with an ohmmeter. If necessary, clean the contacts.

As shown in the simplified block diagram, Figure 4, the RC network consists basically of two precision resistors and capacitors. The effective resistances R_1 and R_2 are varied by the three banks of ten push-button switches, and the capacitors C_1 and C_2 are varied by the frequency multiplier switch.

Engaging any of the thirty push-buttons including all three zeros simultaneously, yields a new value of R_1 and R_2. The correct value of R_1 and R_2 as each push button is engaged is shown in Figure 5. Since the values of R_1 and R_2 are varied by the three banks of the push-button switches, a defective resistor may be localized more easily by checking the values of R_1 and R_2 associated with one bank of ten push-button switches at a time. By engaging the zero button of the bank of any ten push-button switches, the precision resistors associated with the switch are disconnected and, therefore, do not contribute to the effective values of R_1 and R_2.

The indicated resistances to the left and right of each push-button, as shown in Figure 5, are the correct values of R_1 and R_2 respectively, when only one push button in any bank of ten push-button switches is operated and the other two banks of ten push-buttons are switched to the zero position.

To measure the effective value of the precision resistors R_1 and R_2, all of which are wired to the push-button switches directly, it is necessary to disconnect two non-precision resistors R364 and R365, located on the under chassis as shown in the bottom view of Figure 7. These two resistors operate in conjunction with the RC network and the frequency vernier.

The effective value of R_2 can be measured by connecting a suitable dc resistance bridge from the output of the main amplifier (cathode of V8) to the input of the main amplifier (grid of V5B). The effective value of R_1 can be measured from the output (cathode) of the AVC amplifier V3 to the junction point of the two precision capacitors C_1 and C_2. This junction point can be located most easily at the pole on the back section of the frequency multiplier band switch. A wire connects from this pole or junction point to the adjacent push-button switch. During these measurements the frequency multiplier switch should be switched to band 5, which is the 100 position of the FREQUENCY MULTIPLIER.

If the measured resistance differs from the indicated resistance as shown in Figure 5, the defective resistor cannot be isolated immediately because the precision resistors are operated in parallel. The precision resistors which may be defective when the indicated and measured resistors are in disagreement are listed below the correct values of R_1 and R_2 as shown in Figure 5. When a discrepancy occurs between the measured value and the correct value of R_1 and R_2, any one or all of the precision resistors listed below the correct

S-301

R_2		R_1
564.2K±1% R307 R308 R309	9	56.42K±1% R317 R318 R319
635.2K±1% R306 R307 R309	8	63.52K±1% R316 R317 R318
726.8K±1% R305 R306 R307	7	72.68K±1% R315 R316 R317
849.4K±1% R304 R305 R306	6	84.94K±1% R314 R315 R316
1.022M±1% R303 R304 R305	5	102.2K±1% R313 R314 R315
1.282M±1% R302 R303 R304	4	128.2K±1% R312 R313 R314
1.72M±1% R301 R302 R303	3	172K±1% R311 R312 R313
2.611M±1% R301 R302	2	261.1K±1% R311 R312
5.423M±1% R301	1	542.3K±1% R311

S-302

R_2		R_1
55.97K±1% R327 R328 R329	9	5.59K±1% R337 R338 R339
62.95K±1% R326 R327 R328	8	6.295K±1% R336 R337 R338
71.94K±1% R325 R326 R327	7	7.194K±1% R335 R336 R337
83.93K±1% R324 R325 R326	6	8.393K±1% R334 R335 R336
100.7K±1% R323 R324 R325	5	10.07K±1% R333 R334 R335
125.9K±1% R322 R323 R324	4	12.59K±1% R332 R333 R334
167.9K±1% R321 R322 R323	3	16.79K±1% R331 R332 R333
251.8K±1% R321 R322	2	25.18K±1% R331 R332
506K±1% R321	1	50.6K±1% R331

S-303

R_2		R_1
5.597K±½% R347 R348 R349	9	557 OHM±½% R357 R358 R359
6.295K±½% R346 R347 R348	8	6.27 OHM±½% R356 R357 R358
7.194K±½% R345 R346 R347	7	717.2 OHM±½% R355 R356 R357
8.393K±½% R344 R345 R346	6	837.3 OHM±½% R354 R355 R356
10.07K±½% R343 R344 R345	5	1.005K±½% R353 R354 R355
12.59K±½% R342 R343 R344	4	1.257K±½% R352 R353 R354
16.79K±½% R341 R342 R343	3	1.677K±½% R351 R352 R353
25.18K±½% R341 R342	2	2.515K±½% R351 R352
50.36K±½% R341	1	5.03K±½% R351

Figure 5. Table of Network Resistance Values

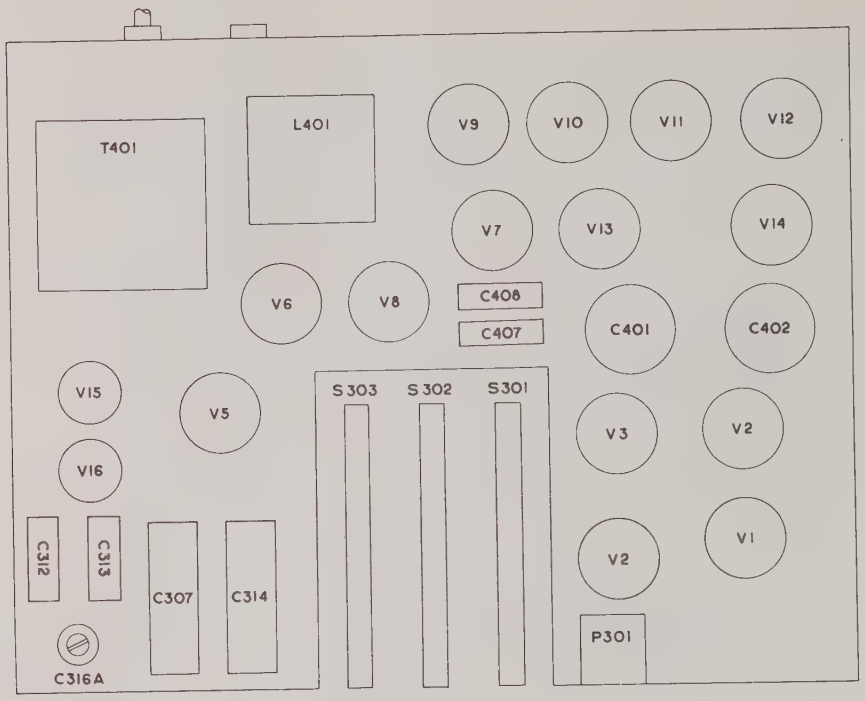

Figure 6. Top View of Chassis

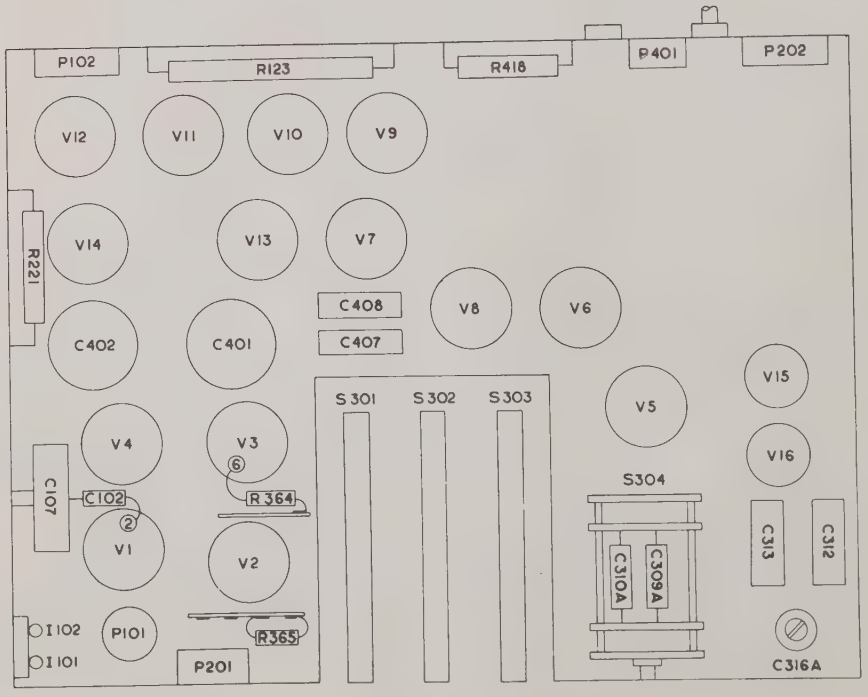

Figure 7. Bottom View of Chassis

value of R_1 and R_2 may be defective. Since most of the precision resistors are common to three push buttons, a defective resistor can be isolated if the indicated and measured values of any three adjacent push-buttons on one bank are in disagreement. The defective resistor will be the one common to all three push buttons. Exercise extreme caution when soldering or unsoldering the precision deposited-carbon resistors. Excessive heat may result in permanent damage. When soldering or unsoldering becomes necessary, draw off as much heat as possible by connecting an alligator clip, or suitable equivalent on the axial connecting lead of the resistor between the soldering point and the body of the resistor.

The values of the precision capacitors C307 through C316 are shown on the schematic and can be checked with a suitable impedance bridge without disconnecting any leads or components. All of the capacitors can be checked on band 1, which is the .01 position of the FREQUENCY MULTIPLIER, excepting C307 and C314, which should be checked on band 2.

6.7 REPLACEMENT OF FREQUENCY DETERMINING CAPACITORS

When it is necessary to replace the frequency determining capacitors C307 through C316, the following procedure is recommended:

These capacitors are pre-selected at the Factory to a particular value so that the frequency calibration and the amplitude of each FREQUENCY MULTIPLIER setting will be correct.

Be sure to refer to the schematic diagram for the Krohn-Hite symbol numbers and install the capacitor which is labeled with the corresponding symbol number.

If, after these capacitors have been installed, the frequency is too high, the new capacitor values can be increased by adding a small trimmer capacitor in parallel with either or both. In recent units there is an adjustable trimmer capacitor already installed across one of these capacitors on the X100, X10 and X1 multiplier positions.

For example, if the frequency is 2% high in the X1 multiplier position, increasing either C315 or C316 4%, or increasing both C315 and C316 2% each, will correct the frequency. If the amplitude is correct and the frequency is high, increase both capacitors.

If the amplitude is low and the frequency high, increase C316. If the amplitude is high and the frequency high, increase C315.

The other frequency determining capacitors of the Model 440A(R) which correspond to and are handled in the same manner as C315 and C316 respectively are:

FREQUENCY MULTIPLIER Position	To Decrease Amplitude: Increase	To Increase Amplitude: Increase
X.01	C314	C307
X.1	C312	C313
X1	C315	C316
X10	C311	C310
X100*	C309	C308

*In the X100 FREQUENCY MULTIPLIER position, C308 and C309 are 1% capacitors and are not pre-selected at the Factory.

NOTE: If, after the new capacitors have been installed, the frequency is too low, the capacitor values are too high and the capacitors must be replaced with units of lower value.

6.8 SQUARE WAVE GENERATOR

When the triode multivibrator, consisting of tubes V15A and V16A is operating properly, V15A is conducting and V16A is nonconducting during the positive excursion of the sine wave signal. During the negative excursion of the sine wave signal V16A becomes conducting and V15A becomes nonconducting. If the Oscillator is set at a frequency of 0.1 cps or lower, the plate of V16A should alternate between +10 volts and +110 volts and can be checked with a voltmeter directly. If the plate of V16A does not alternate between these two voltages, V15A and V16A are not functioning properly and their wiring, components, voltage readings and resistance readings to ground should be checked.

The pentode multivibrator, consisting of tubes V15B and V16B, is triggered directly from the plate of the triode multivibrator V16A. If the triode multivibrator is working properly, the plate of the pentode multivibrator tube, V15B, should alternate from -20 volts to +10 volts and the plate of the other, V16B, should alternate between -5 volts and +5 volts.

If the plates of V15B and V16B do not alternate between these voltages they are not functioning properly and their components, wiring, voltage readings and resistance readings to ground should be checked.

SECTION 7

CALIBRATION AND ADJUSTMENT

7.1 INTRODUCTION

This Calibration and Adjustment Procedure is provided for the purpose of facilitating the maintenance, repair and calibration of Krohn-Hite Oscillators in the field. The steps outlined follow very closely the operations which are performed on the instrument by our Final Test Department, and strict adherence to this procedure should restore the instrument to its original operating efficiency and accuracy. If any difficulties are encountered or any questions arise which are not covered by this procedure, please consult our Factory Service Department. Some of the specifications given in the following proce-

dure are tighter than our general specifications. This is to ensure, in test, an adequate safety factor. These tolerances therefore should not be used for purposes of accepting or rejecting the instrument.

7.2 TEST EQUIPMENT REQUIRED

a. AC VTVM - reading from 10 mv full scale to 100 volts (rms) full scale, db scale preferable.

b. Oscilloscope - having direct coupled horizontal and vertical amplifiers with at least 10 mv/cm sensitivity. Frequency response to at least 2 mc.

c. Precision frequency and period counter - capable of measuring frequency from 100 cps to 100 kc and period from 1000 seconds to 1 millisecond.

d. Vacuum-tube voltohmmeter - reading to 500 V dc. Do not use this instrument for ac signal measurements.

e. AC voltmeter - to measure line voltage.

f. Variable auto transformer - to adjust the line voltage from 105 to 125 or from 210 to 250 volts, as required. Refer to Section 2.2.3.

g. Distortion meter or wave analyzer - capable of measuring distortion below 0.1% from 20 cps to 20 kc.

7.3 GENERAL

a. All dc voltage measurements are to be made with the VTVM, and are made with respect to ground (chassis), unless otherwise specified.

b. All measurements are made operating at rated line voltage (115 or 230 volts) having less than 1% distortion (unless otherwise specified).

c. Give the instrument a thorough visual inspection, looking particularly for oil leaks, discoloration of the chassis or components, loose or broken wires, poor soldering connections, etc.

d. Check the operation of all push-buttons and switches.

e. Check that all tubes are seated firmly in the correct sockets and that all the heaters light.

f. If the following tests uncover discrepancies and the remedy given does not locate the source of trouble, refer to Section 6.

7.4 DETAILED PROCEDURE

7.4.1 VOLTAGE MEASUREMENTS

Measure the following dc voltages:

Voltage Check	Check Point	Tolerance	Possible remedy
B minus	Negative end of C402	-100 to -190 volts	Check V12 or R407 and R408
B plus	Plate of V15A	Within ±5 volts from above step, but opposite polarity	Check R410 and R413
1st AVC stage	Plate of V1A	+120 to +180 volts	Check R101 and R106
Output dc level	Sine wave output terminal	±0.1 volt	Adjust P202 (output dc level adjust)
AVC dc level	Cathode of V3	±0.3 volts	Adjust P102 (AVC dc level adjust)
2nd AVC stage	Plate of V2	+110 to +140 volts	Adjust R117A and R131
Diode minus	Pin #3 of V4	-5 to -12 volts	V4 components
Diode plus	Pin #5 of V4 to cathode of V3	-1 to -5 volts	V4 components
Unregulated B plus	Plate of V10	+285 to +345 volts	Check V9
2nd stage of Main Amplifier	Plate of V6	+80 to +110 volts	Check R213

7.4.2 HEATER VOLTAGES AND RIPPLE

a. Read the ac voltage across heater pins of V1.

   Tolerance: 4.5 to 5.5 volts.

b. Read the ac voltage across heat pins of V2.

   Tolerance: 5.7 to 6.9 volts.

c. Measure the ac ripple from the center arm of P401 (Hum adjust potentiometer) to ground.

Tolerance: Less than 200 millivolts.

If incorrect, check for a ground in the heater wiring.

7.4.3 OUTPUT POWER

a. Set the Oscillator frequency to 1000 cps.

b. Connect an ac VTVM and Oscilloscope across the SINE WAVE output of the Oscillator.

c. Connect a 1 K resistor across the SINE WAVE output terminals of the Oscillator.

d. With the RMS VOLTS Control set maximum clockwise, adjust P101 (amplitude adj. potentiometer) for an output voltage of 10.5 volts. Signal should be undistorted.

e. Check that the output is undistorted over the correct operating voltage range (105-125 or 210-250 volts). If distorted change V9.

f. Return line voltage to middle of operating range (115 or 230 volts).

7.4.4 HUM MODULATION

Set Oscillator frequency to 6 kc and observe any amplitude modulation of the sine wave. Repeat at 100 kc and with the 1 K resistor removed from across the output.

Tolerance: Less than 0.5% modulation

If incorrect, try changing V1 or V2.

7.4.5 GENERAL OPERATION OF ALL BANDS

Check operation of Oscillator at all push button and multiplier settings.

7.4.6 RMS VOLTS CONTROL CALIBRATION

Set the RMS VOLTS control knob for optimum agreement with panel screening.

7.4.7 CALIBRATION-ADJUSTMENT OF HIGH FREQUENCY TRIMMERS

a. Set the Oscillator frequency to 10 kc.

b. Set Frequency Vernier to OFF.

c. Connect a frequency counter to the Oscillator output. The frequency should read 10 kc ±1%. If it does not, adjust C309A to bring it within tolerance.

d. Set the Oscillator frequency to 99.9 kc. The frequency should read 99.9 kc ±3%. If it does not, adjust C102 and repeat at 10 kc.

7.4.8 FREQUENCY CALIBRATION

a. With the frequency counter and AC VTVM connected across the SINE WAVE output, check the frequency calibration and amplitude at the frequencies below.

b. Set the RMS VOLTS control for a reading of 10 volts rms at 1 kc. Do not readjust the RMS VOLTS control during the remainder of the frequency calibration. Below 10 cps the oscilloscope must be used to measure the amplitude.

Frequency Setting	Tolerance		Remedy	
	Frequency	Amplitude	Frequency off Tolerance**	Amplitude low*
99.9 kc	±3%	±0.75 db	Adjust C102	
10.0 kc	±1%	±0.25 db	Adjust C309A	Increase C308 and Decrease C309
11.1 kc	±3%	±0.75 db	Check Network Resistors	
22.2 kc	±3%	±0.75 db	Check Network Resistors	
33.3 kc	±3%	±0.75 db	Check Network Resistors	
1.00 kc	±1%	±0.25 db	Adjust C301A	Increase C310 and Decrease C311
2.00 kc	±1%	±0.25 db	Check Network Resistors	
3.00 kc	±1%	±0.25 db	Check Network Resistors	
4.00 kc	±1%	±0.25 db	Check Network Resistors	
5.00 kc	±1%	±0.25 db	Check Network Resistors	
6.00 kc	±1%	±0.25 db	Check Network Resistors	
7.00 kc	±1%	±0.25 db	Check Network Resistors	
8.00 kc	±1%	±0.25 db	Check Network Resistors	
9.00 kc	±1%	±0.25 db	Check Network Resistors	
9.99 kc	±1%	±0.25 db	Check Network Resistors	
100 cps	±1%	±0.25 db	Adjust C316A	Increase C316 and Decrease C315
999 cps	±1%	±0.25 db	Adjust C316A	Increase C316 and Decrease C315
10.0 cps	±1%	±0.25 db	TRIM C312 and/or C313	Increase C313 and Decrease C312
99.9 cps	±1%	±0.25 db	TRIM C312 and/or C313	Increase C313 and Decrease C312

Frequency Setting	Tolerance		Remedy	
	Frequency	Amplitude	Frequency off Tolerance**	Amplitude low*
9.99 cps	±1%	±0.25 db	TRIM C307 and/ or C314	Increase C307 and Decrease C314
1.00 cps	±1%	±0.25 db	TRIM C307 and/ or C314	Increase C307 and Decrease C314
0.90 cps	±3%	±0.25 db	Check Network Resistors	
0.80 cps	±3%	±0.25 db	Check Network Resistors	
0.70 cps	±3%	±0.25 db	Check Network Resistors	
0.60 cps	±3%	±0.25 db	Check Network Resistors	
0.50 cps	±3%	±0.25 cps	Check Network Resistors	
0.40 cps	±3%	±0.25 db	Check Network Resistors	
0.30 cps	±3%	±0.25 db	Check Network Resistors	
0.20 cps	±3%	±0.25 db	Check Network Resistors	
0.10 cps	±3%	±0.25 db	Check Network Resistors	
0.01 cps	±3%	±0.75 db	Adjust R128	Check for leakage in C307 or C314
.02 cps	±3%	±0.75 db	Check Network Resistors	
.03 cps	±3%	±0.75 db	Check Network Resistors	
.04 cps	±3%	±0.75 db	Check Network Resistors	
.05 cps	±3%	±0.75 db	Check Network Resistors	
.06 cps	±3%	±0.75 db	Check Network Resistors	
.07 cps	±3%	±0.75 db	Check Network Resistors	
.08 cps	±3%	±0.75 db	Check Network Resistors	
.09 cps	±3%	±0.75 db	Check Network Resistors	

NOTES:

* If amplitude is high, change capacitors in the opposite directions.

** In correcting excessive errors in either frequency or amplitude, if the other function (amplitude or frequency respectively) is in error at all, change only the one of the two capacitors mentioned which will correct both. If frequency is low decrease capacitors; if frequency is high, increase capacitors. One capacitor must be changed by twice the % error or two capacitors each changed by the % error.

7.4.9 FREQUENCY AND AMPLITUDE STABILITY VS. LINE VOLTAGE

Check the frequency and amplitude at 9.99 kc as the line voltage is varied over the appropriate operating range (105-125 or 210-250 volts).

Tolerance: Frequency ±0.05% for a ±10% change in line voltage.
Amplitude ±0.05 db for a ±10% change in line voltage.

NOTE

Change line voltage to middle of operating range (115 or 230 volts).

7.4.10 FREQUENCY VERNIER CHECK

With the FREQUENCY VERNIER set to OFF, set the Oscillator push buttons to 001 with the FREQUENCY MULTIPLIER on 10. The frequency should read 10 cycles/sec ±1%, and the amplitude should be 10 volts ±1 db. If the frequency is low increase either R368 or R369 depending on which helps the amplitude in the right direction. Turn the vernier clockwise until the counter reads 20 cps. The vernier knob should now read 10 ±15%. If it does not, rotate the knob on the vernier shaft. If the amplitude is low at this point decrease R365. Turn the vernier full clockwise. The frequency should be reading between 30 and 40 cps and the amplitude should be still 10 volts ±1 db. If the frequency or amplitude is low decrease R365 and repeat all of this step.

7.4.11 AVC AMPLIFIER DISTORTION

Set the Oscillator to 0.09 cps. Connect the scope to the cathode of V3. The signal should be between 3 to 5.5 volts and not noticably distorted. If the signal is distorted change I101 and I102, the AVC elements, and reset the RMS amp. adj. (P101). Repeat at 99.9 kc frequency setting.

7.4.12 OUTPUT AMPLIFIER DISTORTION

Connect the scope to the control grid of V5B. Signal should be between 25 to 90 millivolts rms and not noticably distorted. If distortion is excessive, adjust R213.

7.4.13 DISTORTION

Using either a wave analyzer or distortion meter proceed to measure the distortion of the Oscillator at the following frequencies. Measure the distortion with and without a 1000 ohm resistive load.

Frequency	Tolerance
20 kc*	Less than 1%
10 kc	Less than 0.1%
1 kc	Less than 0.1%
100 cps	Less than 0.1%
20 cps	Less than 0.1%

Equipment that will measure distortion of this order of magnitude below 20 cps and above 50 kc is not known to be commercially available, therefore this procedure does not cover the measurements beyond this range. Krohn-Hite will, however, supply to anyone upon request information on how these measurements are performed at the Factory.

*If the distortion measured at 20 kc is excessive, adjust trim capacitor, C109.

It is essential that certain precautions be observed when a wave analyzer or distortion meter is used to measure very low values of distortion. Experience at Krohn-Hite does not cover all makes of distortion measuring equipment, but the same general considerations should apply to all wave analyzers and distortion meters.

When using a distortion meter to measure very low values of distortion, the following information and precautions apply:

a. Great care should be taken to ensure that the instrument is properly calibrated in accordance with the manufacturer's instructions. In particular, since the panel meter indicates internally generated power supply ripple voltage, it is important that any hum-balance adjustments be made with great care. Before making a measurement, check that no meter indication is observed on any range when the input terminals are shorted.

b. This type of instrument usually has an internal amplifier which has some inherent distortion. Consequently there will be an indication of distortion, even when a pure sine wave voltage is applied. The amount of internal distortion is usually small, and only becomes important when the low end of the most sensitive scale is being read. A typical residual distortion specification is 0.1%, and it is assumed that an actual value of 0.05% might reasonably be expected in a reputable manufacturer's instrument. This amount of residual distortion leads to a reading error of only 1% when the total reading is 5%, but when a total distortion value of 0.1% is being measured, the reading error can be as high as 50%.

c. At very low distortion levels the phase relationship between input harmonic voltages and those generated within the distortion meter becomes important because the panel meter indicates the magnitude of the vector sum of these voltages. Depending on relative phase and amplitude, an imput harmonic voltage could produce a distortion reading anywhere from zero to many times its actual value.

When using a wave analyzer to measure very low values of distortion, the following information and precautions apply:

a. Great care should be taken to ensure that the instrument is properly calibrated in accordance with the manufacturer's instructions. This is most important.

b. When this instrument is used as a distortion meter, the sensitivity controls are adjusted to give a full scale (100%) meter reading when the tuning control is carefully set to the fundamental frequency of the input signal. Once the analyzer sensitivity and input signal amplitude adjustments have been made, they must not be disturbed while the harmonics are being measured.

c. When this instrument is used as a frequency selective voltmeter to measure relative fundamental and harmonic voltage amplitudes, an input sensitivity setting must be selected which gives an "on scale" meter reading when the tuning control is carefully set to the fundamental frequency of the input signal. If the analyzer does not have a variable sensitivity control, the input signal amplitude can be adjusted to give a full scale meter reading, if desired, to facilitate the measurement. Once the analyzer sensitivity and input signal amplitude adjustments have been made, they must not be disturbed while the harmonics are being measured.

d. When using the analyzer to measure low levels of distortion by either of the above methods, do not increase the analyzer sensitivity or increase the input signal amplitude independently in an attempt to obtain a better harmonic voltage amplitude or percentage reading. The input circuits of the analyzer will be overloaded by the fundamental frequency voltage and the resulting distortion will lead to erroneous readings even though the meter appears to be functioning properly.

e. With regard to residual instrument distortion and the phase relationship between these harmonics and input signal distortion harmonics, the same considerations apply as in the distortion meter.

7.4.14 HUM

Repeat step 7.4.13 with the wave analyzer or distortion meter set to measure hum.

Tolerance: Less than 10 millivolts.

Adjust Hum Adjust Potentiometer, P401, to minimize hum. Disconnect the wave analyzer or distortion meter.

7.4.15 SQUARE WAVE TESTS

a. Amplitude:

Connect the oscilloscope to the square wave output of the Oscillator. Set the Oscillator frequency to 100 cps. Measure the peak to peak amplitude of the square wave presentation.

Tolerance: 10 volts peak to peak ±10%.

If incorrect, adjust R514.

b. Symmetry:

With the oscilloscope measure the time of the positive half cycle compared to the time of the negative half cycle. It should be symmetrical to within ±8%.

If incorrect, adjust R502.

c. Output dc level:

Measure the output dc level of the square wave with a VTVM. It should be between ±0.25 volts. If too much positive, adjust R517. If too much negative, adjust R511. Switch Oscillator frequency to 99.9 kc. The dc on the output should remain between ±0.25 volts. If it goes positive, shunt R508. If it goes negative, shunt R507. If any resistors were changed or added up to now on step 7.4.15, recheck parts a, b and c.

d. Rise Time:

Calibrate the oscilloscope sweep time for 0.2 microseconds/cm. Syncronize the scope so that the rise of the square wave can be seen clearly on the face of the scope. Measure the rise time, which is the horizontal displacement between the 10% and 90% points.

Tolerance: 0.5 microseconds.

If incorrect, change V15 or V16 and recheck all of step 7.4.15.

e. Output Impedance:

Connect a 1500 ohm resistor across the square wave terminals. The output voltage should drop to approximately 5 volts peak to peak.

SECTION 8

PARTS LIST

8.1 INTRODUCTION

This section provides listings for the replaceable parts of the Model 440A and Model 440AR Push-button Oscillators. The components are divided into three main headings: (1) Capacitors, (2) Resistors, and (3) Other Components.

The manufacturers Code and Part No. columns give the manufacturer and his part number for each component. The manufacturers' part numbers listed may differ from the part numbers of the components found in the instrument. These substitutions, however, are direct replacements.

Some of the listings include asterisks which refer to the following notes:

*Components recommended to be purchased from Krohn-Hite Corporation.
**Non-repairable items.
***Frequency determining capacitors having a basic tolerance of ±5%; they are selected and trimmed for proper frequency and amplitude calibration.

MANUFACTURERS CODE

Abbreviations	Name	Address
A-B	Allen-Bradley Company	Milwaukee 4, Wisconsin
AER	Aerovox Corporation	New Bedford, Mass.
BU	Bussman Manufacturing Co.	St. Louis, Missouri
CA	The Carborundum Co.	Niagra Falls, New York
C-D	Cornell-Dublier Elec. Co.	South Plainfield, N. J.
C-H	Cutler-Hammer Inc.	Milwaukee, Wisconsin
CI	Cinema Engineering	Burbank, California
CTS	Chicago Telephone Supply Corp.	Elkhart, Indiana
EL	Elmenco	Willimantic, Conn.
GE	General Electric Co.	Schenectady, New York
IRC	International Resistance Co.	Philadelphia, Pa.
K-H	Krohn-Hite Corp.	Cambridge, Mass.
RCA	Radio Corp. of America	Somerville, N. J.
R-I	Resistors, Inc.	Chicago, Illinois
SP	Sprague Electric Company	North Adams, Mass.
TEL	Telefunken	c/o American Elite Co. Long Island City, N. Y.
UC	Ucinite Company	Newtonville, Mass.
W-L	Ward Leonard Elec. Co.	Chicago, Illinois

8.2 ORDERING PARTS

When ordering parts from Krohn-Hite Corporation, the following information should be supplied: (1) Model Number of the Instrument, (2) Serial Number of the Instrument, (3) Description, (4) Manufacturer, and (5) Part No.

8.3 PARTS LIST

SCHEMATIC SYMBOL	DESCRIPTION	MFG.	MFG. PART NO.
	CAPACITORS		
C101	100 mmf 500V 20% Mica	EL	DM15C101M
C102	0.9 to 7 mmf Variable Capacitor	EL	T50010 Type 40
C103	75 mmf 500V 5% Mica	EL	DM15C750J
C104	Factory Adjst. Approx. 39 mmf Mica	EL	
C105	TRIM, approx. 100 mmf Mica	EL	
*C105A	1 mmf 500V 10% Mica	EL	CM20C (±.5)
C106	24 mmf 500V 20% Mica	EL	DM15C240M

SCHEMATIC SYMBOL	DESCRIPTION	MFG.	MFG. PART NO.
C107	(TRIM) 0.5 mf 400V 20% Paper	C-D	PM 4P5
C108	.001 mf 500V 20% Ceramic	SP	40C230A
C109	1.5-20 mmf Variable Capacitor	EL	T50210 Type 402
C110	10 mmf 500V 20% Mica	EL	DM15C100M
C201	.01 mf 500V 20% Ceramic	SP	29C9B6
C202	TRIM (Approx. 51 mmf Mica)	EL	
C203	47 mmf 500V 5% Mica	EL	DM15C470J
C204	.001 mf 500V 20% Ceramic	SP	40C230A
C205	51 mmf 500V 20% Mica	EL	DM15C510M
C206	.01 mf 500V 20% Ceramic	SP	29C9B6
C207	.001 mf 500V 20% Ceramic	SP	40C230A
C208	.001 mf 500V 20% Ceramic	SP	40C230A
C209	24 mmf 500V 20% Mica	EL	DM15C240M
C210	.01 mf 600V 20% Paper	SP	160P10306
*C301A	3.3 mmf 500V 10% Mica	EL	CM19C(3.3)K
*C301B	4.7 mmf 500V 10% Mica	EL	CM19C(4.7)K
C303	18 mmf 500V 10% Mica	EL	CM19C180K
*C304	5.1 mmf 500V 10% Mica	EL	CM19C(5.1)K
C306A	39 mmf 500V 20% Mica	EL	DM15C390M
*C307	10 mf 75V ***Met. Mylar	C-D	MFT104
*C308	1100 mmf 500V 1% Mica	EL	CM25D112F
*C309	800 mmf 500V 5% Mica	EL	CM25C801J
C309A	8-60 mmf Variable Capacitor	EL	T50410 Type 40
C310	.01 mf 100V ***Mylar	K-H	BCM101
C310A	37-250 mmf Variable Capacitor	EL	T51610 Type 426
C311	.01 mf 100V ***Mylar	K-H	BCM101
*C312	1 mf 200V ***Met. Mylar	C-D	MF111
*C313	1 mf 200V ***Met. Mylar	C-D	MF111
*C314	10 mf 75V ***Met. Mylar	C-D	MFT104
C315	0.1 mf 100V ***Mylar	K-H	BCM100
C316	0.1 mf 100V ***Mylar	K-H	BCM100
C316A	1400-3055 mmf Variable Capacitor	EL	PD521502
C400	.01 mf 500V 20% Ceramic	SP	29C9B6
*C401	4 mf 330VAC 20% Oil	AER	P104J2
C401A	0.18 mf 400V 20% Paper	SP	160P18404
C402	4 mf 330VAC 20% Oil	AER	P104J2
C403	.01 mf 500V 20% Ceramic	SP	29C9B6
C404	.01 mf 500V 20% Ceramic	SP	29C9B6
C405	.001 mf 500V 20% Ceramic	SP	40C230A
C406	.001 mf 500V 20% Ceramic	SP	40C230A
C407	1 mf 400V 20% Oil	C-D	WC 4100-3
C408	1 mf 400V 20% Oil	C-D	WC 4100-3
C409	24 mmf 500V 20% Mica	EL	DM15C240M
C410	10 mmf 500V 20% Mica	EL	DM15C100M
C501	2 mmf 500V 10% Mica	EL	CM19C(2.0)K
C501A	1.5-20 mmf Variable Capacitor	EL	T50210 Type 402
C502	10 mmf 500V 20% Mica	EL	DM15C100M
*C503	1 mmf 500V 10% Mica	EL	CM20C(±.5)

SCHEMATIC SYMBOL	DESCRIPTION			MFG.	MFG. PART NO.
*C504	6.8 mmf	500V	10% Mica	EL	CM19C(6.8)K
			RESISTORS		
R101	910K	1/2W	5% Composition	A-B	EB-9145
R102	5.6M	1/2W	5% Composition	A-B	EB-5655
R103A	9.1K	1/2W	5% Composition	A-B	EB-9125
R103B	15K	1/2W	5% Composition	A-B	EB-1535
R104	82K	1/2W	10% Composition	A-B	EB-8231
R105	39K	1/2W	10% Composition	A-B	EB-3931
R106	22K	1/2W	5% Composition	A-B	EB-2235
R107	100K	1/2W	10% Composition	A-B	EB-1041
R108	200K	1/2W	5% Composition	A-B	EB-2045
R109	1.2K	1/2W	10% Composition	A-B	EB-1221
R110	TRIM (Approx. 750K Composition)			A-B	
R110A	100K	1/2W	5% Composition	A-B	EB-1045
R111	10M	1/2W	5% Composition	A-B	EB-1065
R111A	TRIM (Approx. 25M Composition)			A-B	
R112	1.5K	1/2W	10% Composition	A-B	EB-1521
R113	100 ohm	1/2W	20% Composition	A-B	EB-1012
R114	15M	1/2W	5% Composition	A-B	EB-1565
R115	12K	1W	5% Composition	A-B	GB-1235
R117	910K	1/2W	5% Composition	A-B	EB-9145
R117A	TRIM (Approx. 15M Composition)			A-B	
R118	100 ohm	1/2W	20% Composition	A-B	EB-1012
R120	TRIM (Approx. 6.8M Composition)			A-B	
R121	1.2M	1/2W	5% Composition	A-B	EB-1255
R122	18K	1/2W	5% Composition	A-B	EB-1835
*R123A	9.1K tapped at 4K, 55W, 5% Wire-wound			K-H	440-910-R123
*R123B	9.1K tapped at 4K, 55W, 5% Wire-wound			K-H	440-910-R123
R124	2K	1/2W	5% Composition	A-B	EB-2025
R125	1.8M	1/2W	5% Composition	A-B	EB-1855
R126	1.2M	1/2W	5% Composition	A-B	EB-1835
R127	TRIM (Approx. 75K Composition)			A-B	
R128	TRIM (Approx. 15M Composition)			A-B	
*R130	100K at 28°C Thermister			CA	763F
R131	TRIM (Approx. 10M Composition)			A-B	
R201	220K	1/2W	5% Composition	A-B	EB-2245
R202	220K	1/2W	5% Composition	A-B	EB-2245
R203	1.2M	1/2W	10% Composition	A-B	EB-1251
R204	1.8M	1/2W	5% Composition	A-B	EB-1855
R205	300K	1/2W	5% Composition	A-B	EB-3045
R206	470 ohm	1/2W	10% Composition	A-B	EB-4711
R207	100 ohm	1/2W	20% Composition	A-B	EB-1012
R208	1.3M	1/2W	5% Composition	A-B	EB-1355
R209	27K	1W	10% Composition	A-B	GB-2731
R210	12K	2W	10% Composition	A-B	HB-1231

SCHEMATIC SYMBOL	DESCRIPTION			MFG.	MFG. PART NO.
R211	27K	1W	10% Composition	A-B	GB-2731
R212	18K	1/2W	10% Composition	A-B	EB-1831
R213	820K	1/2W	5% Composition	A-B	EB-8245
R214	100 ohm	1/2W	20% Composition	A-B	EB-1012
R215	56K	1/2W	5% Composition	A-B	EB-5635
R216	100K	1/2W	5% Composition	A-B	EB-1245
R217	1M	1/2W	5% Composition	A-B	EB-1055
R218	100 ohm	1/2W	20% Composition	A-B	EB-1012
R219	1M	1/2W	10% Composition	A-B	EB-1051
R220	470K	1/2W	10% Composition	A-B	EB-4741
*R221	4K	20W	5% Wire-wound	W-L	20S4000WL
R301	5.423M	1W	1/2% Deposited-carbon	IRC	Type DCF
R302	5.036M	1W	1/2% Deposited-carbon	IRC	Type DCF
R303	5.036M	1W	1/2% Deposited-carbon	IRC	Type DCF
R304	2.611M	1/2W	1/2% Deposited-carbon	IRC	Type DCC
R305	2.518M	1/2W	1/2% Deposited-carbon	IRC	Type DCC
R306	2.518M	1/2W	1/2% Deposited-carbon	IRC	Type DCC
R307	1.72M	1/2W	1/2% Deposited-carbon	IRC	Type DCC
R308	1.679M	1/2W	1/2% Deposited-carbon	IRC	Type DCC
R309	1.679M	1/2W	1/2% Deposited-carbon	IRC	Type DCC
R311	542.3K	1/2W	1/2% Deposited-carbon	IRC	Type DCC
R312	503.6K	1/2W	1/2% Deposited-carbon	IRC	Type DCC
R313	503.6K	1/2W	1/2% Deposited-carbon	IRC	Type DCC
R314	261.1K	1/2W	1/2% Deposited-carbon	IRC	Type DCC
R315	251.8K	1/2W	1/2% Deposited-carbon	IRC	Type DCC
R316	251.8K	1/2W	1/2% Deposited-carbon	IRC	Type DCC
R317	172K	1/2W	1/2% Deposited-carbon	IRC	Type DCC
R318	167.9K	1/2W	1/2% Deposited-carbon	IRC	Type DCC
R319	167.9K	1/2W	1/2% Deposited-carbon	IRC	Type DCC
R321	506K	1/2W	1/2% Deposited-carbon	IRC	Type DCC
R322	503.6K	1/2W	1/2% Deposited-carbon	IRC	Type DCC
R323	503.6K	1/2W	1/2% Deposited-carbon	IRC	Type DCC
R324	251.8K	1/2W	1/2% Deposited-carbon	IRC	Type DCC
R325	251.8K	1/2W	1/2% Deposited-carbon	IRC	Type DDC
R326	251.8K	1/2W	1/2% Deposited-carbon	IRC	Type DDC
R327	167.9K	1/2W	1/2% Deposited-carbon	IRC	Type DDC
R328	167.9K	1/2W	1/2% Deposited-carbon	IRC	Type DDC
R329	167.9K	1/2W	1/2% Deposited-carbon	IRC	Type DDC
R331	50.6K	1/2W	1/2% Deposited-carbon	IRC	Type DDC
R332	50.36K	1/2W	1/2% Deposited-carbon	IRC	Type DDC
R333	50.36K	1/2W	1/2% Deposited-carbon	IRC	Type DDC
R334	25.18K	1/2W	1/2% Deposited-carbon	IRC	Type DDC
R335	25.18K	1/2W	1/2% Deposited-carbon	IRC	Type DCC
R336	25.18K	1/2W	1/2% Deposited-carbon	IRC	Type DCC
R337	16.79K	1/2W	1/2% Deposited-carbon	IRC	Type DCC
R338	16.79K	1/2W	1/2% Deposited-carbon	IRC	Type DCC
R339	16.79K	1/2W	1/2% Deposited-carbon	IRC	Type DCC

SCHEMATIC SYMBOL	DESCRIPTION	MFG.	MFG. PART NO.
R341	50.36K 1/2W 1/2% Deposited-carbon	IRC	Type DCC
R342	50.36K 1/2W 1/2% Deposited-carbon	IRC	Type DCC
R343	50.36K 1/2W 1/2% Deposited-carbon	IRC	Type DDC
R344	25.18K 1/2W 1/2% Deposited-carbon	IRC	Type DDC
R345	25.18K 1/2W 1/2% Deposited-carbon	IRC	Type DDC
R346	25.18K 1/2W 1/2% Deposited-carbon	IRC	Type DDC
R347	16.79K 1/2W 1/2% Deposited-carbon	IRC	Type DDC
R348	16.79K 1/2W 1/2% Deposited-carbon	IRC	Type DCC
R349	16.79K 1/2W 1/2% Deposited-carbon	IRC	Type DCC
R351	5.030K 1/2W 1/2% Deposited-carbon	IRC	Type DCC
R352	5.030K 1/2W 1/2% Deposited-carbon	IRC	Type DCC
R353	5.030K 1/2W 1/2% Deposited-carbon	IRC	Type DCC
R354	2.512K 1/2W 1/2% Deposited-carbon	IRC	Type DCC
R355	2.512K 1/2W 1/2% Deposited-carbon	IRC	Type DCC
R356	2.512K 1/2W 1/2% Deposited-carbon	IRC	Type DCC
R357	1.671K 1/2W 1/2% Deposited-carbon	IRC	Type DCC
R358	1.671K 1/2W 1/2% Deposited-carbon	IRC	Type DCC
R359	1.671K 1/2W 1/2% Deposited-carbon	IRC	Type DCC
R360	220K 1/2W 10% Composition	A-B	EB-2241
R361	1.5K 1/2W 10% Composition	A-B	EB-1521
R362	27K 2W 10% Composition	A-B	GB-2731
R363	180K 1/2W 5% Composition	A-B	EB-1845
R364	1.8M 1/2W 5% Composition	A-B	EB-1855
R365	180K 1/2W 5% Composition	A-B	EB-1845
R368	TRIM (Part of P301: Approx. 25M Comp.)	A-B	
R369	TRIM (Part of P301: Approx. 25M Comp.)	A-B	
R400	2.2K 1/2W 10% Composition	A-B	EB-2221
R400A	120K 1/2W 10% Composition	A-B	EB-1241
R401	470K 1/2W 10% Composition	A-B	EB-4741
R402	100 ohm 1/2W 20% Composition	A-B	EB-1012
R403	6.8K 1/2W 10% Composition	A-B	EB-6821
R404	1.8M 1/2W 10% Composition	A-B	EB-1851
R405	1.2M 1/2W 10% Composition	A-B	EB-1251
R406	220K 1/2W 10% Composition	A-B	EB-2241
R407	330K 1/2W 5% Composition	A-B	EB-3345
R408	330K 1/2W 5% Composition	A-B	EB-3345
R409	18K 2W 10% Composition	A-B	HB-1831
*R410	155K 1/2W 1% Wire-wound	IRC	CEC-TO
R411	220K 1/2W 5% Composition	A-B	EB-2245
R412	2.7M 1/2W 5% Composition	A-B	EB-2755
*R413	150K 1/2W 1% Wire-wound	IRC	CEC-TO
R414	510K 1/2W 5% Composition	A-B	EB-5145
R415	1.3M 1/2W 5% Composition	A-B	EB-1355
R416	1.8M 1/2W 5% Composition	A-B	EB-1835
R417	100 ohm 1/2W 20% Composition	A-B	EB-1012
R418	6.75K 30W 5% Wire-wound	K-H	440-675-R418
R419	100 ohm 1/2W 20% Composition	A-B	EB-1012

SCHEMATIC SYMBOL	DESCRIPTION	MFG.	MFG. PART NO.
R501	75K 1/2W 5% Composition	A-B	EB-7535
R502	TRIM (Approx. 7.5M Composition)	A-B	
R503	1.2M 1/2W 10% Composition	A-B	EB-1251
R504	47K 2W 10% Composition	A-B	HB-4731
R505	470K 1/2W 5% Composition	A-B	EB-4745
R506	56K 1/2W 10% Composition	A-B	EB-5631
R507	FACTORY ADJUST. (Approx. 100K Comp.)	A-B	
R507A	100 ohm 1/2W 20% Composition	A-B	EB-1012
R508	FACTORY ADJUST. (Approx. 100K Comp.)	A-B	
R509	8.2K 1/2W 5% Composition	A-B	EB-8225
R510	47K 2W 10% Composition	A-B	HB-4731
R511	47K 2W 10% Composition	A-B	HB-4731
R512	82K 1/2W 10% Composition	A-B	EB-8231
R513	5.1K 1/2W 5% Composition	A-B	EB-5125
R514	TRIM (Approx. 1.6K Composition)	A-B	
R515	8.2K 2W 5% Composition	A-B	HB-8225
R516	68K 1/2W 5% Composition	A-B	EB-6835
R517	TRIM (510K - ∞ Composition)	A-B	

OTHER COMPONENTS

F401	Fuse, 2A, Slow-blow (at 105-125 volts)	BU	MDL-2
	Fuse, 1A, Slow-blow (at 210-250 volts)	BU	MDL-1
*I101	AVC Bulb	GE	344
*I102	AVC Bulb	GE	344
I401	Lamp, Pilot	GE	51
*L401	Choke, 8 HY at 150MA	K-H	C-100-8
*P101	Potentiometer, 10K, 2W	A-B	70059
*P102	Potentiometer, 100K, 2W	A-B	40576
*P201	Potentiometer, 5K, 2W	A-B	30703
*P202	Potentiometer, 100K, 2W	A-B	40576
**P301	Assembly, Vernier	K-H	440-AR-P301
P401	Potentiometer, 500 ohm, 0.2W	CTS	JF7516
*S301	Switch, push-button, 10 ganged sections	K-H	440-S301
*S302	Switch, push-button, 10 ganged sections	K-H	440-S301
*S303	Switch, push-button, 10 ganged sections	K-H	440-S301
*S304	Switch, Rotary	K-H	440-AS4
S401	Switch, Toggle, SPST	C-H	828K16
*T401	Transformer, Power	K-H	P-100-32
V1	Tube, Type 12AX7A	RCA	12AX7A
V2	Tube, Type 6EJ7/EF184	TEL	6EJ7/EF184
V3	Tube, Type 6V6	GE	6V6

SCHEMATIC SYMBOL	DESCRIPTION	MFG.	MFG. PART NO.
V4	Tube, Type 6H6	RCA	6H6
V5	Tube, Type 12AX7A	RCA	12AX7A
V6	Tube, Type 6EJ7/EF184	TEL	6EJ7/EF184
V7	Tube, Type 6EJ7/EF184	TEL	6EJ7/EF184
V8	Tube, Type 6AU5-GT	RCA	6AV5-GT
V9	Tube, Type 5V4	GE	5V4
V10	Tube, Type 6AU5-GT	RCA	6AU5-GT
V11	Tube, Type 6SL7/WGT	RCA	6SL7/WGT
V12	Tube, Type OG3	TEL	OG3
V13	Tube, Type 6SL7/WGT	RCA	6SL7/WGT
V14	Tube, Type 6V6	GE	6V6
V15	Tube, Type 6U8	TEL	6U8
V16	Tube, Type 6U8	TEL	6U8

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